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Marketing New England Poultry

8. Effects of Firm Size and Production Density on Spatial Costs for an Integrated Broiler Marketing Firm

By Clark R. Burbee, Edwin T. Bardwell, and William F. Henry

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE

in cooperation with the

Marketing Economics Division,
Economic Research Service,
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This is part of a Northeast Regional Project, NEM-21, "Adjustments Needed in Marketing Northeastern Poultry Products", a cooperative study involving Agricultural Experiment Stations in the Northeast Region and supported in part by regional funds and funds from the Economic Research Service, United States Department of Agriculture.

Preface and Acknowledgements

This bulletin is the eighth in a series being issued by the Agricultural Experiment Station, University of New Hampshire, in cooperation with the Economic Research Service, United States Department of Agriculture.

The series is concerned with various aspects of poultry marketing in New England. Previous publications in the series with their New Hampshire Experiment Station Bulletin numbers are: 1) *Characteristics of the Processing Industry* (444), 2) *Economies of Scale in Chicken Processing* (450), 3) *Capital Accumulation Potential of Broiler Growers* (475), 4) *Structure and Performance of the Assembly System* (476), 5) *Effects of Firm Size and Production Density on Assembly Costs* (482), and 6) *Economies of Scale in Hatching and Cost of Distributing Broiler Chicks* (483). A report in progress is 7) *Economics of Mixing and Distributing Broiler Feed.* Two companion reports published by the Agricultural Experiment Station, University of Massachusetts are *Freight Rates on Feed, Central Territory Origins to New England and Middle Atlantic States* (508) and *Freight Rates and the Eastern Poultry Industry* (533).

The objectives of this publication are to determine and to summarize the unit costs of the spatial activities of an integrated poultry system and to show how these costs are affected by changing 1) firm size, 2) production density, and 3) distance.

The authors appreciate the cooperation of all who in their many ways have made this series possible. Special thanks are accorded Mr. George B. Rogers, Economic Research Service, U. S. Department of Agriculture, who has been intimately involved with the planning and conduct of the research of this entire series.

Summary and Conclusions

The spatial activities of broiler assembly and chick and feed distribution are an integral part of the typical broiler producing and marketing firm. The purpose of this report is to investigate how these costs are affected by changes in firm size and volume and increases in broiler production density.

The unit cost of each activity was derived for six firms ranging in size from an annual volume of 4.15 million pounds of live broilers to 69.16 million pounds, with broiler production density at three levels. The densities considered were 1,000, 5,000, and 25,000 pounds of 3.5 pound live broilers per square mile per year. A model was developed and budgeting was used to derive the resource requirements and the cost for each activity.

Broiler assembly is the major spatial cost, followed by feed and chick distribution. As firm size, and thus volume handled, is increased at any one of the three density levels, the unit broiler assembly cost increases. The unit feed distribution cost also increases continuously with increasing firm size at the two lower density levels. At the highest density level, the unit cost decreases slightly and then increases with increases in firm size. The unit chick distribution cost decreases over a range of firm sizes before it begins to increase.

At the 1,000 and 5,000 pound density levels, the total unit spatial cost increases with increasing firm size. The cost increases from 1.425 cents a pound for a firm handling 4.15 million pounds of live broilers to 2.095 cents for a firm handling 34.58 million pounds at the 1,000 pound density level. At the 5,000 pound density level, the cost increases from 1.007 cents a pound for the firm handling 4.15 million pounds to 1.463 cents for the firm handling 69.16 million pounds annually. At the highest density level considered, the cost at first decreases from .816 cents a pound for the firm handling 4.15 million pounds annually to .786 cents a pound for the 12.45 million pound firm. Further enlargement in firm size results in increasing unit cost up to .963 cents a pound for the firm handling 69.16 million pounds.

With constant firm size and increases in production density, a firm can reduce spatial costs substantially. Increasing density from 1,000 to 5,000 pounds per square mile per year offers reductions ranging from $17,000 for the firm handling 4.15 million pounds to $303,000 for the firm handling 34.58 million pounds a year. Reductions are not as substantial when density is increased from the 5,000 to the 25,000 pound level. The annual reductions range from $8,000 to $138,000 for the above range in firm sizes. The two larger firms processing 51.87 and 69.16 million pounds would have reductions of $239,000 and $346,000 respectively.

An equation was derived for estimating the combined spatial cost per pound of live broiler for chick and feed delivery and bird assembly. This equation assumes that all plant facilities are located at a central point in the production area and that delivery operations originate at this point and assembly operations terminate at it. This equation is useful in estimating the changes in spatial cost that would result from shifting the location of production units relative to the central facilities. The equation is: $Y = 0.634 + 0.015X$; where Y is the cost in cents per pound and X is the one way road mileage between the center of the production area and the location of the production unit.

The results of this report indicate that a firm considering expansion in volume with constant density will face increased spatial cost. For the firm seeking reductions in cost without changes in volume, substantial savings may be realized through increases in broiler production density.

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Marketing New England Poultry

8. Effects of Firm Size and Production Density on Spatial Costs for an Integrated Broiler Marketing Firm

By Clark R. Burbee, Edwin T. Bardwell, and William F. Henry[1]

I. Introduction

During the past decade, firms in the highly competitive broiler industry have made adjustments to maintain or improve their competitive positions. One course of action has been to integrate or coordinate the various dissimilar but continuous stages of broiler production and marketing. The typical firm operates plants for processing broilers, hatching chicks and manufacturing formula feed. Since the practice is still to contract broiler production on farms in the area surrounding the firm's plants, the firm has to perform the spatial activities of distributing feed and chicks to the farms and assembling finished broilers at the processing plant.

The density or concentration of broiler production attained by a firm can have a major effect on its competitive position. A firm that increases broiler production density reduces the average length of haul for chicks, feed, and live broilers which theoretically results in a lower unit cost. On the other hand, a firm that increases its plant in size and output in order to lower unit costs and increases broiler production by enlarging the production area at the same density level may increase total unit cost. The increase in costs due to spatial factors may be greater than the additional economies gained from increases in plant size. Consequently, a firm considering expansion of plant size and output must also consider the effect on spatial costs before a decision can be made.

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The studies of the spatial activities of broiler assembly and chick and feed distribution had the following objectives to:[2]

1) Determine the relationship between increasing firm size and unit spatial cost at each of three broiler production density levels.

2) Determine the relationship between increasing production density and unit spatial cost for each of six firm sizes.

The objectives of this report are to:

1) Summarize and determine the total unit cost of the spatial activities, broiler assembly and chick and feed distribution, in relation to increasing firm size and production density.

2) Determine the potential reductions in cost from increasing production density.

3) Determine the effect of distance on the unit spatial cost.

The research method used is the budgetary or synthetic model construction and operation of model firms to derive costs. This method is adopted since it is essential that the results of the analysis of each activity be comparable, additive, and related to the capacity and volume of the primary activity of the firm, broiler processing. Production functions for each activity are developed from technical data provided by cooperating firms. Costs and prices are standardized and applied to the input requirements to derive least-cost solutions. This method allows the development of costs for specified sizes and outputs of firms and eliminates many of the intra-firm inefficiencies and variations that exist.

II. The Spatial Model

Six model processing plants are the basic units for establishing the requirements of all the other activities of the firm. These processing plants range in hourly capacity from 600 to 10.000 broilers and have annual outputs ranging from 4.15 million to 69.16 million pounds (live weight).

Live broilers are produced at three production density levels for each of the six firms. The lowest level considered is 1.000 pounds per square mile per year, a level most firms have been able to surpass. The intermediate level is 5.000 pounds per square mile per year and is typical for many firms. The highest level considered is 25.000 pounds per square mile per year, which is an extremely dense production situation.

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[2] Henry, W. F. and C. R. Burbee, *Marketing New England Poultry, 5. Effects of Firm Size and Production Density on Broiler Assembly Costs.* University of New Hampshire, Agricultural Experiment Station Bulletin No. 482, April 1964.

Burbee, C. R. and E. T. Bardwell, *Marketing New England Poultry. 6. Economies of Scale in Hatching and Cost of Distributing Broiler Chicks.* University of New Hampshire, Agricultural Experiment Station Bulletin No. 483, 1964.

Burbee, C. R. and E. T. Bardwell, *Marketing New England Poultry, 7. Economics of Mixing and Distributing Broiler Feed,* Manuscript in preparation.

The broiler producing area for each firm is assumed to be a perfect circle with the processing, hatching, and feed manufacturing facilities at the center. The size of the area is determined by the size of the firm and the broiler production density. Table 1 lists the firms, their volumes, and the radius of the producing area for each density level.

Table 1. Annual Volumes and Radii of Broiler Producing Areas for Six Model Firms Producing Broilers at Three Density Levels.

Firm	Annual Volume			Radii of Producing Area Density Level		
	Broilers	Chicks	Feed	1,000 lb.	5,000 lb.	25,000 lb.
	(million lbs.)	(million lbs.)	(thousand tons)	(miles)		
A	4.15	1.24	5.2	36.4	16.3	7.3
B	12.45	3.71	15.6	63.0	28.2	12.6
C	24.90	7.42	31.2	89.0	39.8	17.8
D	34.58	10.31	43.4	104.9	46.9	21.0
E	51.87	15.47	65.1	128.5	57.5	25.7
F	69.16	20.63	86.8	148.4	66.4	29.7

Table 2. Annual Volumes and Radial and Road Distances to Average Location in Each Band for Three Production Density Levels.

Band	Annual Volumes			Radial and Road Distance to Average Location Density Level*					
	Broilers	Chicks	Feed	1,000 lb.		5,000 lb.		25,000 lb.	
				radius	road	radius	road	radius	road
	(million lbs.)	(millions)	(thousand tons)	(miles)					
I	4.15	1.24	5.2	25.7	33.2	11.5	14.0	5.1	6.2
II	8.30	2.47	10.4	51.4	67.9	23.0	29.5	10.3	12.4
III	12.45	3.71	15.6	77.1	102.6	34.5	45.1	15.4	19.3
IV	9.68	2.89	12.2	97.3	129.9	43.5	57.2	19.5	24.8
V	17.29	5.16	21.7	117.3	156.9	52.5	69.3	23.5	30.2
VI	17.29	5.16	21.7	138.8	186.0	69.1	83.7	27.7	35.9

* The average location in each band is derived by the following equation:

$$A = \sqrt{\frac{X^2 + Y^2}{2}}$$

Where A is the average airline distance, X is the radial distance to the inner perimeter of the band, and Y is the radial distance to the outer perimeter of the band. This distance is converted to the oneway road mile distance by one of two equations. If the average distance is less than 10 miles, the following equation is used:

$$RM = 1.196A$$

Where RM is the road mileage and A is the average airline distance. For distances exceeding ten miles, the following equation is used:

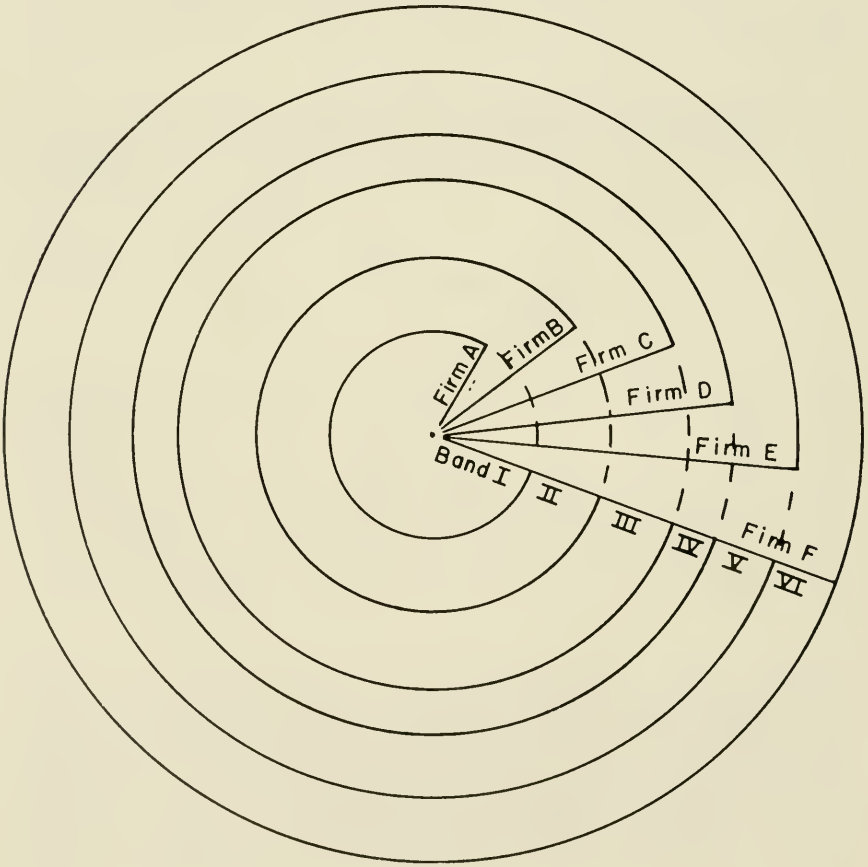
$$RM = -1.534 + 1.531A$$

Where RM is the road mileage and A is the average airline distance.

With production density held constant, any increase in firm size requires a proportionate increase in the size of the broiler producing area. The result is a small circle enclosed by five rings or bands (Figure 1). The small circle represents the broiler producing area required for the smallest firm size. Moving out from the center, each successive band represents the area that must be added with each successive increase in firm size.

Each of the six producing bands is assumed to be a separate entity with a specified broiler producing capability. For each day of processing operations, a specified quantity of broilers is assembled in each band. The production density in all bands is the same. In order to assure a continuous supply, an equivalent number of "day old" broiler chicks plus an additional number to compensate for mortality during the growing out period are distributed in the bands. During the growing out period, the required quantities of several feed formulations are distributed into each band. Table 2 gives the annual quantities of broilers produced and chicks and feed distributed into each band.

Figure 1. Broiler Producing Areas for Six Firm Sizes with Broiler Production at a Constant Density.



The geometric model serves as the basis for establishing several physical relationships for each density level and, ultimately, the average and marginal cost. The average location of all broilers in a band is assumed to be on a line of equal radius from the center of the production area which divides the band area into halves. The radial distance between the average location in each band and the plant facility is determined and converted into road mileage and travel time for use in determining the required quantity of resources.

The road network serving the producing area consists of five primary roads extending out from the center and a large number of secondary roads that branch off from the primary roads. Table 2 lists the radial and road mileages to the average location in each band for each density situation.

The budgeting technique is used for deriving least cost solutions for each activity performed by each firm at each density level. The broiler assembly solutions were derived first and they establish the criteria for the two distribution activities.

The first step is to establish least-cost solutions for each activity in each band. This is accomplished by inserting the various combinations of resources into a matrix and determining the combination that minimizes inputs. These input quantities are converted to input costs by application of standardized cost rates.

The second step is to minimize the spatial activity cost to the firm. The bands in the producing area of each firm are combined into all possible combinations to determine whether one set of resources can service two or more bands instead of a set for each band. Combining eliminates considerable quantities of travel mileage, hours of travel, men, and trucks which reduces costs.

Several assumptions apply to the analysis of each activity to assure consistency and to have the results additive:

1) The processing plant of each model firm operates 247 eight-hour days a year which establishes the size and capacity requirements of the broiler production and spatial activities.

2) All broilers are grown-out in eight weeks, and average 3.5 pounds live weight at the time of processing.

3) The work day for any resource used in the performance of any of the spatial activities is restricted to a maximum of ten hours.

4) Those phases of each spatial activity performed at the broiler production unit are carried out by personnel of the firm without assistance of the grower.

5) The maximum broiler flock size in any band cannot exceed the number of birds that are assembled in two consecutive work days. This condition establishes maximum flock size at 9,600 in band I, 19,200 in band II, 28,800 in band III, 22,400 in band IV, and 40,000 in bands V and VI. Breeder flock sizes are assumed to be 2,595 in band I, 5,190 in band II, 7,785 in band III, 6,055 in band IV, and 5,406 in bands V and VI.

In addition, each activity has other assumptions peculiar to the nature of the operation.

III. Broiler Assembly

Broiler assembly operations are conducted for each day of scheduled processing. A quantity of broilers sufficient to exactly meet the number scheduled for processing is assembled at the plant. Trucks, pick-up laborers, and supervisors are dispatched from the plant to the broiler producing units. The pick-up laborers and foremen travel by station wagon. At the farm the crew, which consists of a foreman, laborers, and the driver of the truck being loaded, prepare for catching and crating birds. The crew proceeds to catch, carry to, and crate the birds on the truck. Once the truck is loaded, the driver secures the load and proceeds to the plant. In the meantime, another truck arrives and the driver prepares it for loading. At the plant, the plant unloading crew unloads the truck and reloads it with empty crates. The driver then proceeds back to the original farm stop or to another farm. When operations are finished at a farm, the crew proceeds to another farm if sufficient time remains in the specified ten-hour day. If not, the crew returns to the plant and is dismissed.

Factors considered in this analysis of each firm size at each density level are: number and size of crews, number and size of trucks, and broiler weight shrinkage. Within limits, these factors can be substituted for one another. This is considered in the derivation of the least cost solutions.

In the analysis, the crew size can range from three to ten men. Labor productivity ranges from a low of 563 pounds per man-hour for a three man crew to a maximum of 949 pounds per man-hour for a nine man crew. A ten man crew has a labor productivity of 942 pounds per man-hour. Crew productivity ranges from 1,690 pounds per hour for a three man crew to 9,400 pounds per hour for a ten man crew.

Two truck sizes are used which are representative of the sizes used by many firms. They are straight trucks with crate capacities of 190 and 220 crates or broiler capacities of 9,975 pounds and 11,550 pounds.

Bird weight shrinkage is an important item, and the loss is generally regarded as a function of the time that birds are in crates. The weight loss increases at a decreasing rate over time.

Broiler assembly costs are categorized under the six headings of labor, truck, shrinkage, management, car, and crate. Labor includes the cost of the truck drivers, pick-up laborers, and foremen. Truck includes the cost of owning and operating the trucks used for hauling broilers. Shrinkage is the value of the weight lost in the assembly operation. Management includes the cost of space and personnel that are required in management and direction of the operation. The crew transportation expenses are for transporting the crews out from and back to the plant. Crate expenses are for the crates used to contain the broilers while in transit between the farm and plant.

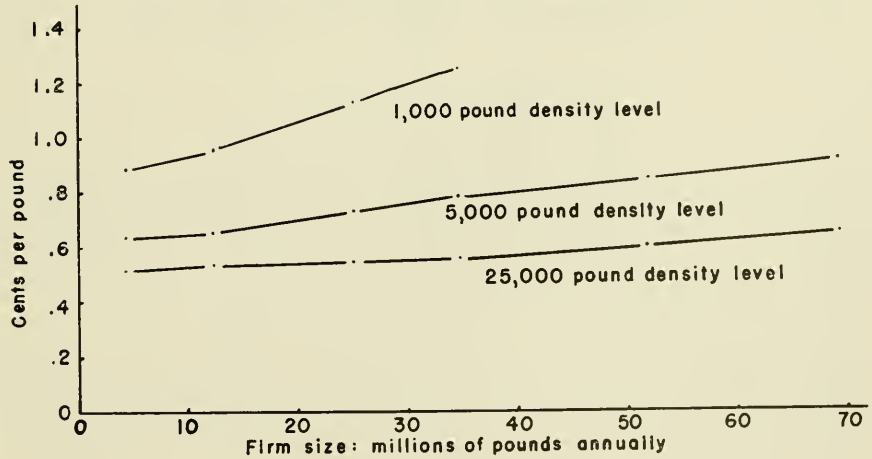
Table 3 is a summary of the assembly costs for the six firms with broiler production density at three levels. At each density level, increasing firm size increases unit assembly cost. At the lowest density level considered, cost increases from 0.881 cents a pound for firm A to 1.255 cents a pound for firm D. Firms E and F cannot assemble the volume required within the ten hour work day limit on resources at this density

Table 3. Broiler Assembly Costs in Cents per Pound of Live Broiler for Six Firm Sizes at Three Density Levels.

Firm	Truck	Labor	Crate	Car	Mgt.	Shrink.	Total
			(cents per pound)				
			1,000 Pound Density Level				
A	.147	.323	.014	.028	.038	.326	.881
B	.177	.335	.012	.028	.028	.375	.955
C	.230	.405	.012	.043	.022	.417	1.129
D	.249	.481	.012	.057	.021	.435	1.255
			5,000 Pound Density Level				
A	.099	.244	.014	.012	.038	.230	.637
B	.104	.253	.013	.008	.028	.241	.647
C	.133	.274	.012	.010	.022	.276	.727
D	.151	.287	.012	.013	.021	.299	.783
E	.163	.315	.012	.018	.019	.327	.854
F	.183	.333	.012	.022	.019	.350	.919
			25,000 Pound Density Level				
A	.084	.200	.011	.005	.038	.179	.517
B	.063	.205	.010	.003	.028	.228	.537
C	.072	.216	.011	.004	.022	.218	.543
D	.075	.217	.011	.004	.021	.229	.557
E	.085	.229	.012	.007	.019	.248	.600
F	.098	.240	.013	.009	.019	.275	.654

level. At the intermediate density level, the cost per pound increases from .637 cents a pound for firm A to .919 cents a pound for firm F. The cost per pound increases from .517 cents to .654 cents a pound over the same firm size range at the highest density level considered. The rate of increase in unit assembly cost with increases in firm size diminishes as production density increases as illustrated in Figure 2.

Figure 2. Broiler Assembly Costs per Pound for Various Size Firms Producing at Three Density Levels.

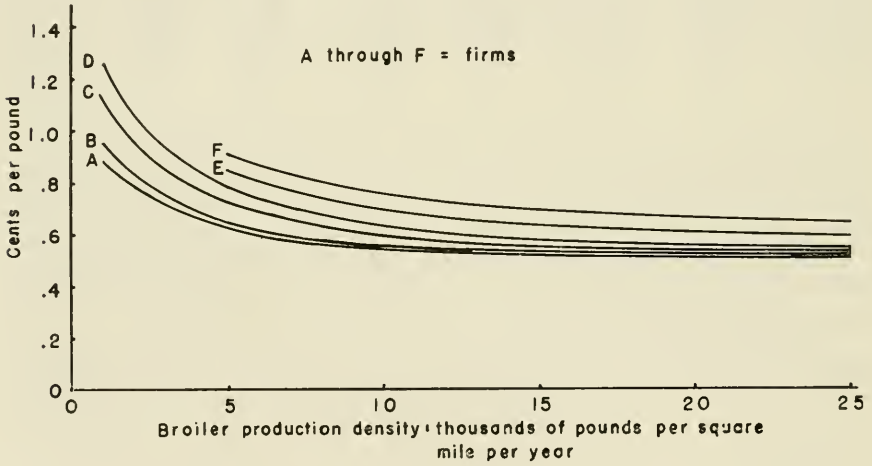


As firm size increases with production density held constant, most of the increase in the unit assembly cost is due to higher unit labor and bird shrinkage costs. Moderate increases occur for truck and crew transportation costs. The unit crate cost remains approximately the same.

Increasing density at any firm size results in a reduced unit assembly cost. However, the per unit cost decreases at a decreasing rate. For example, firm D has a reduction of .472 cents a pound when density is increased from the 1,000 to 5,000 pound level. Increasing density from the 5,000 to the 25,000 pound level results in a substantially smaller absolute decline, .226 cents a pound.

Figure 3 illustrates broiler assembly costs for six firm sizes at various production density levels. The per unit cost decreases rapidly for all firm sizes as production density is increased up to levels of 8,000 to 12,000 pounds per square mile per year. Further increases in production density do not result in substantial decreases in the unit assembly cost. For any given density level between 1,000 and 25,000 pounds, successive increases in firm size result in a higher unit assembly cost.

Figure 3. Broiler Assembly Costs per Pound at Various Production Density Levels for Six Firms.



IV. Chick Distribution

Chick distribution consists of hauling "day old" broiler chicks from the hatchery to the broiler production units. Upon arrival, the driver and possibly a helper check the broiler house and then unload and place the chicks in the house. The boxes used to transport the chicks are reloaded in the truck and the driver proceeds to additional farms or returns to the hatchery.

The chick distribution activity differs in two respects from either broiler assembly or feed distribution. First, chicks are extremely small and light in weight compared to the mass and weight of finished broilers or feed. Many hatcheries can easily ship in one truck on a single trip the output of a day's hatch. Second, chick distribution is not regularly

scheduled over five days a week, but occurs according to the hatchery's setting and hatching schedule. Eggs are set and chicks removed 21 days later at a frequency of two, four, or six times a week. Generally, the number of days of hatch removal per week increases with hatchery size and output in order to even out the workload and improve the efficiency of operations.

For this analysis, firm A removes hatches and distributes chicks twice a week; firm B, four times a week; and firms C, D, E and F, six times a week. The number of chicks distributed per week ranges from 25,000 for firm A to 417,500 for firm F. Included in this number of chicks is an allowance for expected mortality during the growing-out period. It is assumed that 4.2 percent of the chicks distributed do not reach market age.

Examination of the truck requirements for hatcheries and truck sizes available for distributing chicks revealed that no one or two sizes would be satisfactory for the six firms. Consequently, truck sizes are matched with the size of the regularly scheduled capacity shipments of the six hatcheries. This resulted in the selection of five truck sizes ranging in load capacity from 14,000 to 34,800 chicks.

Crew size on each truck is limited to a maximum of two men, a driver and a helper. The crew performs all the unloading and chick placing functions at the farm. The grower performs the house preparation and has the house ready when the chicks arrive.

Table 4 presents the per unit cost of chick distribution for the six firm sizes with density at three production levels. Costs are expressed

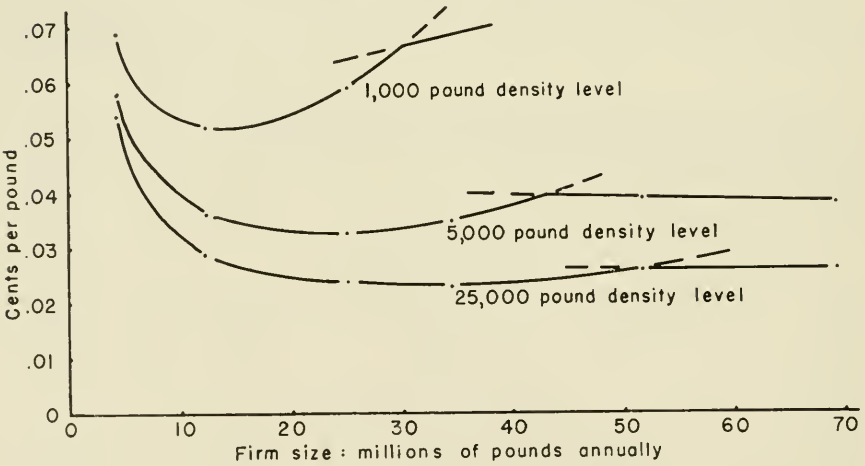
Table 4. Chick Distribution Costs in Cents per Pound of Live Broiler for Six Firms at Three Density Levels.

Firm	Truck	Labor	Mgt.	Total
		(cents per pound)		
		1,000 Pound Density Level		
A	.046	.021	.002	.069
B	.028	.023	.001	.052
C	.027	.031	.001	.059
D	.034	.035	.001	.070
		5,000 Pound Density Level		
A	.041	.015	.002	.058
B	.018	.017	.001	.036
C	.015	.017	.001	.033
D	.014	.020	.001	.035
E	.017	.021	.001	.039
F	.016	.021	.001	.038
		25,000 Pound Density Level		
A	.039	.013	.002	.054
B	.015	.013	.001	.029
C	.010	.013	.001	.024
D	.009	.013	.001	.023
E	.011	.014	.001	.026
F	.010	.015	.001	.026

in cents per pound of live broiler to be processed instead of on a per chick basis to compensate for the mortality losses and keep this cost additive with the other stages. The distribution costs are listed under three headings: truck, labor, and management.

At the lowest density level considered, the distribution cost decreases initially from 0.069 cents a pound for firm A to 0.052 cents for firm B. With further increases in firm size, the unit distribution cost increases to 0.070 cents a pound for firm D, the largest firm size considered at this density level. At the 5,000 pound density level, the unit distribution cost also initially decreases with increasing firm size. The cost decreases from 0.058 cents a pound for firm A to 0.033 cents a pound for firm C. Further increases in firm size increase the distribution cost to 0.039 cents a pound for firm E. Increasing firm size from E to F results in the unit cost remaining substantially the same, 0.038 cents a pound. At the highest density level considered, 25,000 pounds, the chick distribution cost decreases from 0.054 cents a pound for firm A to 0.023 cents a pound for firm D with only a moderate increase in cost with further increases in size. Figure 4 illustrates the effect of increasing size on unit cost for the three density levels.

Figure 4. Chick Distribution Costs per Pound of Live Broiler for Various Size Firms Producing Broilers at Three Density Levels.

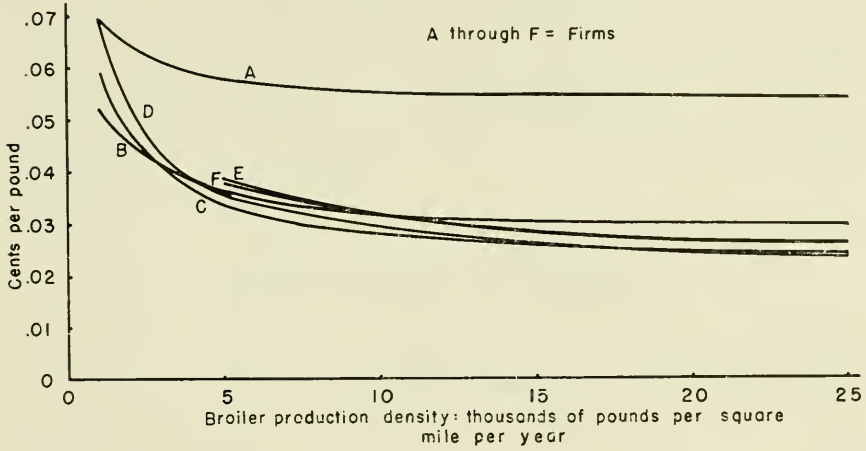


The initial decreases in the distribution cost with increasing firm size at a given density level is the result of several factors. The positive effect on costs caused by increasing the size of the producing area is initially more than offset by two cost-reducing adjustments. As hatchery size increases, the number of distribution days is increased and a larger size truck is substituted in place of a smaller size truck. Initially, these adjustments are sufficient to reduce the unit distribution cost. Eventually, the cost-increasing effect of increasing area is sufficient to offset these diminishing-cost reductions.

Increasing density at any firm size has the same effect as it has on broiler assembly costs. Chick distribution cost decreases at a decreasing rate. For example, firm D can reduce the per unit distribution cost by 0.035 cents a pound when density is increased from 1,000 to 5,000 pounds, but the reduction is only 0.012 cents a pound when density is increased from 5,000 to 25,000 pounds.

Figure 5 illustrates the relationship between the average cost per pound and increasing production density for six firms distributing chicks. The unit cost decreases at a decreasing rate for the six firms as density is increased. Increasing density beyond 10,000 pounds for firms A and B has little effect on the average cost. The larger size firms, C through F, experience continued decreases in unit cost up to a density level of approximately 15,000 to 20,000 pounds with only minor decreases in cost with further increases in density.

Figure 5. Chick Distribution Costs per Pound of Live Broiler Produced at Various Density Levels for Six Firms.



V. Feed Distribution

Each firm produces and distributes all the feed required by the broiler growing and hatching egg activities.[1] The feed produced consists of five basic formulations, two for the broilers and three for the breeders. Broilers consume a starter ration and a finisher. Breeders are assumed to be purchased as day old chicks and are fed a breeder starter ration for six weeks. a breeder grower for the following fourteen weeks, and a breeder layer during the following 40-week laying period.

The quantity of feed mixed and distributed is a function of the production coefficients and firm size. It is assumed that broilers have a

[1] The assembly of hatching eggs has not been included as a spatial activity. The cost on the basis of a per pound of broiler would probably range between .01 and .03 cents.

feed conversion of 2.10 or .82 pounds of starter and 1.28 pounds of finisher for each pound of live weight. Breeders are assumed to consume six pounds of starter and fourteen pounds of grower per bird. During the laying period, 8.5 pounds of feed are consumed per dozen eggs hatched. On the basis of these coefficients, approximately 85 percent of the feed mixed is broiler feed. Table 1 shows the quantities of feed distributed by each firm annually.

All feed is assumed to be delivered in bulk form by 12-ton-capacity bulk trucks. The driver of each truck performs the loading operation at the feed mill, drives the truck, and unloads the truck at the farms without any direct assistance. There is a managerial staff to organize and direct operations.

Only one truck size is used in this activity. It is the largest straight type allowed under existing institutional conditions in several New England states. The truck has four three-ton compartments for carrying from one to four different orders or formulations. Unloading is accomplished by an air system mounted on the truck.

Table 5 lists the feed distribution costs for each firm at each density level. Costs are categorized as truck, driver, and other. The last category includes the following items: managerial and clerical salaries, supplies, utilities, office space and equipment, and garage space.

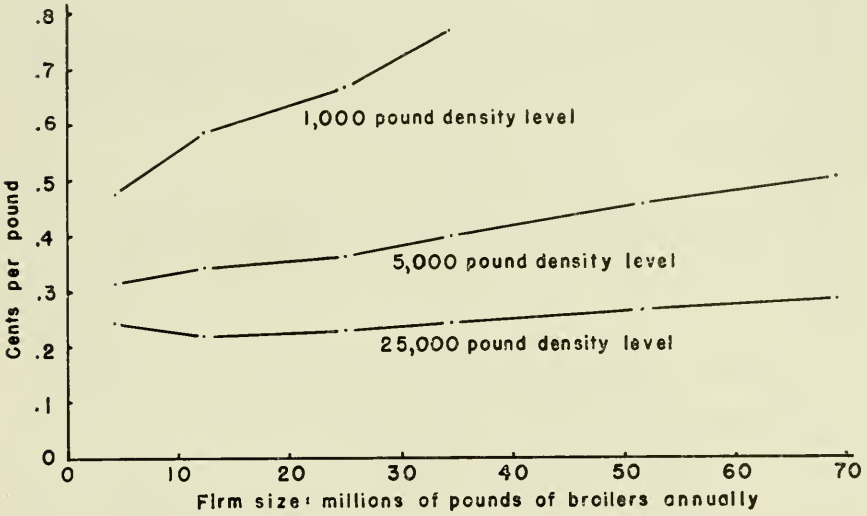
At the lowest density level, the feed distribution cost per pound of finished broiler increases from 0.475 cents for firm A to 0.770 cents for firm D. Increasing firm size at the intermediate density level has the same effect on the unit cost for feed. The cost increases continuously

Table 5. Feed Distribution Costs in Cents per Pound of Live Broiler for Six Firms at Three Density Levels.

Firm	Truck	Driver	Other	Total
		(cents per pound)		
		1,000 Pound Density Level		
A	.296	.135	.044	.475
B	.400	.151	.037	.588
C	.465	.167	.032	.664
D	.552	.187	.031	.770
		5,000 Pound Density Level		
A	.169	.099	.044	.312
B	.205	.102	.036	.343
C	.222	.108	.030	.360
D	.254	.117	.029	.400
E	.301	.127	.027	.455
F	.342	.137	.027	.506
		25,000 Pound Density Level		
A	.117	.084	.044	.245
B	.106	.080	.034	.220
C	.118	.082	.030	.230
D	.127	.085	.028	.240
E	.147	.089	.026	.262
F	.164	.093	.026	.283

from 0.312 cents a pound for firm A to 0.506 cents a pound for firm F. At the highest density level considered, the unit cost decreases initially and then increases. The cost decreases from 0.245 cents a pound for firm A to 0.220 cents for firm B and then increases to 0.283 cents for firm F. Figure 6 illustrates the relationship between average cost and increasing firm size for six firms distributing feed at three density levels.

Figure 6. Feed Distribution Costs per Pound of Live Broiler for Various Size Firms Producing Broilers at Three Density Levels.



With increasing firm size at a given density level, the truck and driver cost increases while the "other" cost category decreases at a decreasing rate. Of the total unit cost, the unit truck cost is by far the largest followed by the unit driver cost and then the "other" cost. At each density level, the unit truck cost increases at a greater rate than the unit driver cost.

Successive increases in density at any firm size reduces the unit feed distribution cost by diminishing amounts. All cost categories decrease with the largest decreases occurring in the unit truck cost. Once production density approaches the 15,000 pound level, further increases in density provide only minor reductions in cost. Figure 7 illustrates the relationships between the unit feed distribution cost for the six firms over the range of production densities considered.

VI. Total Spatial Activity Cost

Table 6 shows the total unit cost for each of the three spatial activities and the combined cost for each firm at each broiler production density level. At the 1,000 pound production density level, the total unit cost increases from 1.425 cents for firm A to 2.095 cents for firm D, the

Figure 7. Feed Distribution Costs per Pound of Live Broiler Produced at Various Density Levels for Six Firms.

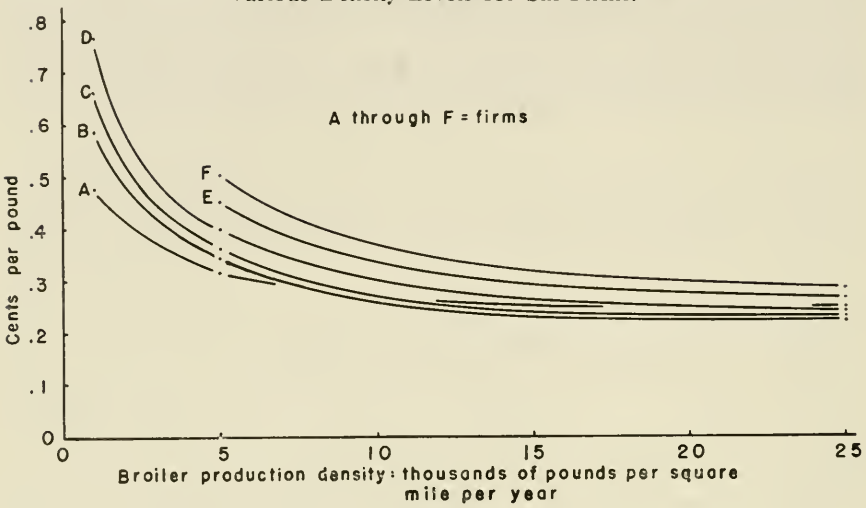


Table 6. Spatial Activity Costs in Cents per Pound of Live Broiler for Six Firms at Three Density Levels.*

Firm	Annual Volume	Radius of Production Area	Costs			
			Broiler Assembly	Chick Distribution	Feed Distribution	Total
	(million lbs.)	(miles)	(cents per pound)			
		1,000 Pound Density Level				
A	4.15	36.4	.881	.069	.475	1.425
B	12.45	63.0	.955	.052	.588	1.595
C	24.90	89.0	1.129	.059	.664	1.852
D	34.58	104.9	1.255	.070	.770	2.095
		5,000 Pound Density Level				
A	4.15	16.3	.637	.058	.312	1.007
B	12.45	28.2	.647	.036	.343	1.026
C	24.90	39.8	.727	.033	.360	1.120
D	34.58	46.9	.783	.035	.400	1.218
E	51.87	57.5	.854	.039	.455	1.348
F	69.16	66.4	.919	.038	.506	1.463
		25,000 Pound Density Level				
A	4.15	7.3	.517	.054	.245	.816
B	12.45	12.6	.537	.029	.220	.786
C	24.90	17.8	.543	.024	.230	.797
D	34.58	21.0	.557	.023	.240	.820
E	51.87	25.7	.600	.026	.262	.888
F	69.16	29.7	.654	.026	.283	.963

* Spatial Activities: (1) Broiler Assembly, (2) Chick Distribution, (3) Feed Distribution.

largest possible firm size at this density level. Over 95 percent of the total unit cost is for broiler assembly and feed distribution, the former accounting for approximately 60 percent and the latter approximately 36 percent of the total. Chick distribution costs are a very small portion of the total. As firm size is increased, the initial decreases in unit chick distribution cost are more than offset by the increases in the unit broiler assembly and feed distribution costs.

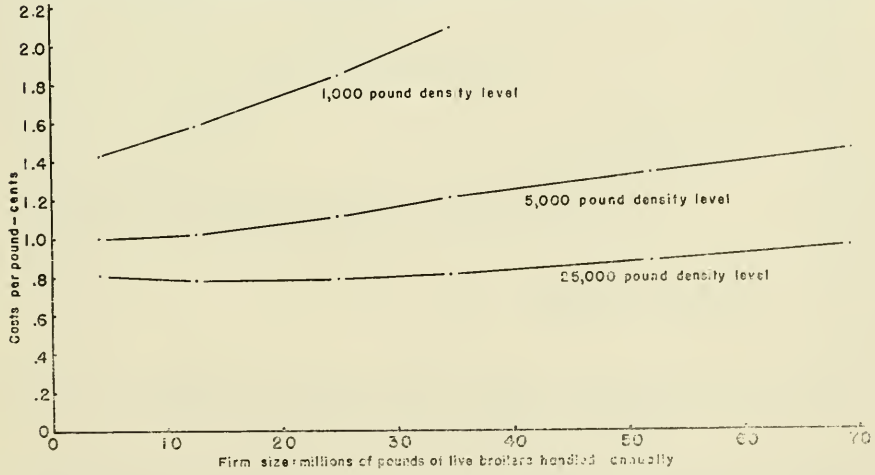
The situation is similar at the 5,000 pound density level. The total unit cost increases continuously from 1.007 cents for firm A to 1.463 cents for firm F. However, the percentage increase in cost with increasing firm size is considerably less. At the 1,000 density level, the total unit cost increased by 47 percent between firms A and D, but the increase at the 5,000 pound density level is only 21 percent over the same range in firm sizes, and 45 percent from firm A to firm F.

At the 25,000 pound density level, there is an initial decrease in the total unit cost as firm size is increased. The cost per pound is .816 cents for firm A and decreases to .786 cents for firm B. The decrease is a result of unit cost decreases for chick and feed distribution amounting to .05 cents. This is only partially offset by a .02 cent rise in the unit assembly cost. The total unit cost increases continuously from firm B to a high of .963 cents for firm F. The percentage increase over the range of firm sizes considered is 18 percent and 22 percent between the firms with the lowest to the highest unit cost.

Figure 8 shows the relationship between firm size and unit cost for the spatial activities at each density level.

Increasing broiler production density reduces total unit spatial cost for a given firm size. For example, for firm D, total unit costs decline from 2.095 cents per pound at 1,000 pounds per square mile to 0.820 cents per pound at 25,000 pounds per square mile.

Figure 8. Spatial Activities Costs per Pound of Live Broiler for Various Size Firms Producing Broilers at Three Density Levels.[1]



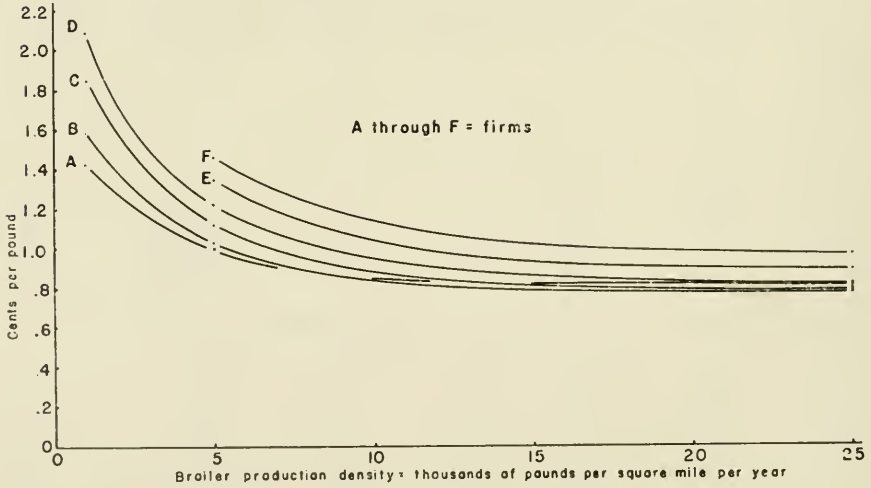
[1] Spatial Activities: (1) Broiler Assembly, (2) Chick Distribution, (3) Feed Distribution.

However, the effect is not the same for all sizes of firms. The absolute and percentage cost reductions become larger as firm size is increased. When density is increased from 1,000 to 25,000 pounds, the decrease in unit cost ranges from a low of .609 cents a pound or 43 percent for firm A to a high of 1.275 cents or 61 percent for firm D. Increasing density from 5,000 to 25,000 pounds results in reductions ranging from a low of .191 cents a pound or 19 percent for firm A to a high of .500 cents or 34 percent for firm F.

On an annual basis, the cost reductions from increasing broiler production density are sizeable. Increasing density from 1,000 to 5,000 pounds offers reductions ranging from $17,000 for firm A to $303,000 for firm D. Increasing density from the 5,000 to 25,000 pound density level results in further reductions ranging from $8,000 for firm A to $138,000 for firm D. Firms E and F would experience cost reductions of $239,000 and $346,000 respectively.

Examination of Figure 9 reveals that only the position of firm A changes in relation to the other firms as production density is increased. As density is increased, each firm experiences decreasing unit spatial costs but the rate of decrease is greater for the larger size firms. At an approximate density level of 9,000 pounds per square mile, the unit spatial cost of firm B becomes less than the unit cost of firm A. At approximately the 14,000 pound density level, the unit cost of firm C becomes less than the unit cost of firm A. Further increases in density do not cause any further changes in the position of the firms in terms of unit cost.

Figure 9. Spatial Activities Costs per Pound of Live Broiler Produced at Various Density Levels for Six Firms.[1]

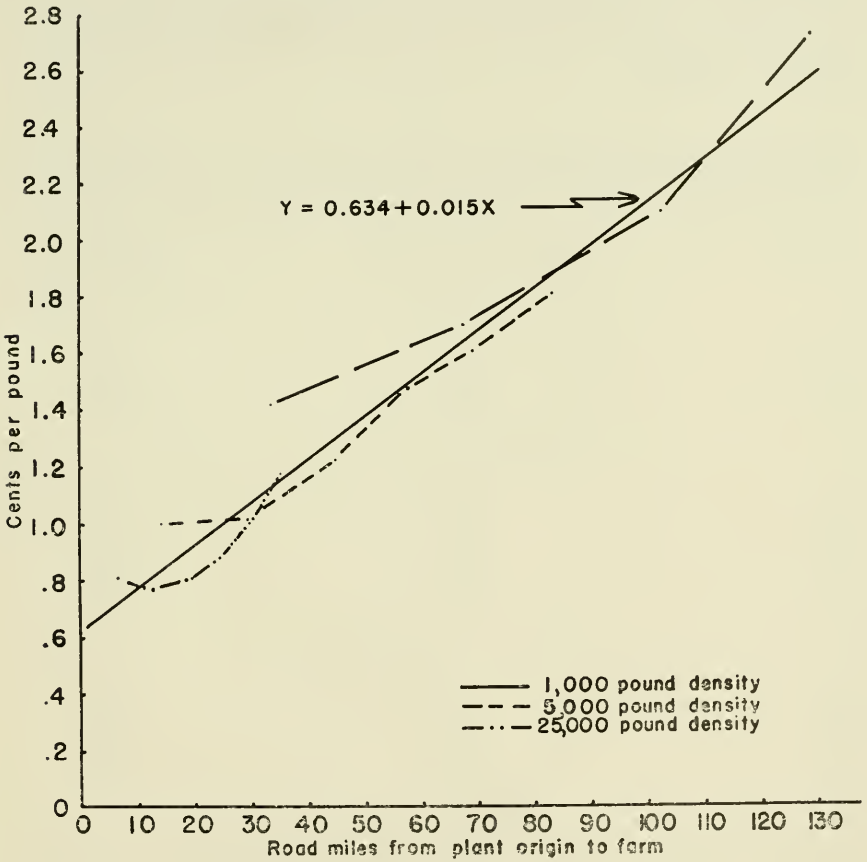


[1] Spatial Activities: (1) Broiler Assembly, (2) Chick Distribution, (3) Feed Distribution.

VII. Effect of Distance on the Unit Spatial Cost

With broiler production density held constant, firms increasing in size must expand their broiler producing areas. Increasing the areas increases the average trip distance and the total unit spatial cost. To illustrate this relationship, the added or marginal spatial cost was derived for each band at each density level from the cost data in Table 6. These unit costs were paired with the respective one way road mileages from the center to the average broiler production locations in the bands in Table 7 and plotted in Figure 10.

Figure 10. Spatial Activities Costs per Pound of Live Broiler at Three Density Levels from a Common Plant Origin to Broiler Production Units Located at Various Distances.[1]



[1] Spatial Activities: (1) Broiler Assembly, (2) Chick Distribution, (3) Feed Distribution.

Plotting of the added costs revealed that cost increases at a relatively constant rate with increases in distance. An equation was calculated for a straight line which minimizes the distance between the points and the line. This equation expresses the relationship between unit cost and distance and is:

$$Y = 0.634 + 0.015\ X^1$$

where Y is the unit spatial cost in cents per pound and X is the one-way road mileage distance between the center of the production area and the location of the broiler production unit. The added cost for each additional mile in road distance is 0.015 cents a pound. The fixed cost, that portion of the cost not associated with distance, is 0.634 cents a pound.

The equation has several practical applications. It can be used to estimate the cost of the spatial activities for servicing broiler production units regardless of the broiler production density experienced by the firm. For example, assume a grower is located 60 road miles from the firm's facilities and has a production of 25,000 birds per flock. The total unit spatial cost to this location is 1.53 cents a pound. On the basis of 3.5 pound birds, the unit cost is 5.36 cents a bird. and the total cost for the flock is $1,340.

Table 7. Total Unit Spatial Costs and Road Mileages from a Common Plant Origin to the Average Broiler Production Location in Each Band.*

Band	One-Way Road Mileage	Unit Cost
	(miles)	(cents per pound)
	1,000 Pound Density Level	
I	33.2	1.425
II	67.9	1.680
III	102.6	2.109
IV	129.9	2.720
	5,000 Pound Density Level	
I	14.0	1.007
II	29.5	1.035
III	45.1	1.214
IV	57.2	1.470
V	69.3	1.608
VI	83.7	1.808
	25,000 Pound Density Level	
I	6.2	.816
II	12.4	.771
III	19.3	.808
IV	24.8	.879
V	30.2	1.024
VI	35.9	1.188

* Spatial Activities: (1) Broiler Assembly, (2) Chick Distribution, (3) Feed Distribution.

[1] Correlation coefficient is .94.

Another use is in estimating potential cost reductions to the firm or the amount that may be added to a grower's income from relocating or shifting from one firm to another. Assume the grower in the above example can relocate to a point only 30 road miles from the firm's facilities with no change in output. The reduction of 30 miles amounts to a decrease of 0.45 cents a pound or approximately $400 per flock. Assuming the grower produces five flocks a year, the annual reduction in cost approximates $2,000. The annual cost of the spatial activities to the new location is $4,700 instead of $6,700 at the old location. This example illustrates the potential reduction in cost that a firm may gain if it shifts production from a grower 60 miles away to a new grower of like capacity 30 miles away.

Persuading a grower to relocate to a closer location will probably require some compensation. In the above example, the firm could offer up to $2,000 more a year for the same output produced at the closer location. But the probability of the firm giving the grower all the savings is rather remote. It is far more likely that the firm and grower will compromise and share the savings.

Assuming that the firm and grower share the savings equally has a substantial effect on the income of the grower. If the grower experiences no change in annual cost or output as a result of the shift in location, his net income is increased by $1,000 a year. If the grower receives a return of three quarters of a cent a bird a week and the growing period is eight weeks, the annual income from five flocks of 25,000 birds each is $7,500. The additional $1,000 makes the gross income $8,500 and represents a 13 percent increase.